

# DENSITY OF CREAM AT LOW TEMPERATURES<sup>1</sup>

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## SUMMARY

The densities of a variety of creams were determined at low temperatures by the pycnometer method to supplement the limited existing data which have been the basis for calculating volume-weight relationships. Linear relationships were found between density and fat, density and total solids, and density and nonfat solids, for cream containing from about 20 to 50% fat. Regression analysis showed that density can be estimated from a simple linear equation based on the percentage of fat in cream almost as accurately as from a multiple regression equation based on the percentages of fat and nonfat solids. The equation for estimating density from the percentage of fat at 9.85 C (based on 57 samples) was:  $\text{Density} = 1.03123 - [0.000770 \times (\text{milk fat percentage})]$ .

Large volumes of commercial cream containing about 40% milk fat are being handled in bulk at low temperature. Consequently, reliable density values at 0 to 10 C are needed for calculating weight to volume relationships pertaining to marketing transactions and yields.

The available weight-volume conversion tables for cream were largely based on early work by the National Bureau of Standards (2). These tables were derived from values obtained between 20 and 50 C. Although determinations were made in the range of 0 and 10 C, only the densities obtained at the higher temperatures were used in their calculations, because they could be well expressed by a simple equation. However, it was suggested that approximate values above 50 and below 20 C could be found by extrapolation. The U. S. Department of Agriculture published a table of computed density values for cream (5). Later, Thomsen (8) presented a table of densities for cream obtained from 3.5% fat milk.

Jenness et al. (3) found that the density of milk fat per se was relatively constant, not being affected significantly by area of source, breed, feed, or season. Also, it has been established that the ratio of nonfat solids to water in cream is the same as that in the milk from which the cream is produced (1). However,

the density of cream is affected significantly by its content of fat and nonfat solids and by temperature.

This investigation of the density of cream at low temperatures was made to supplement existing information and to obtain data needed in the preparation of weight-volume tables for practical use.

## EXPERIMENTAL METHOD

Density was determined by the pycnometer method, using the specially designed pycnometers and equipment described previously (9). It was found that because of the viscous nature of cream, filling the pycnometers could be expedited by the use of gravity with gentle suction instead of using funnels. Subsidiary experiments showed that the use of suction had no appreciable effect on the density values. The samples were warmed to from 30 to 36 C, depending upon their viscosity, before being drawn into the pycnometers.

Comparative experiments in which samples of high-fat cream were held in the pycnometers at 0.95 and 9.85 C for 2, 3, 4, and 6 hr indicated that the density attained a state of equilibrium in about 4 hr. Rishoi and Sharp (6) showed by specific heat measurements that when cream was cooled to temperatures within the range of 0 to 20 C, the phase adjustment of the fat approached a relatively stable state in about 4 hr, the major change being complete within 2 hr. They (7) also found by dilatometer studies that the maximum contraction of the fat in cream, cooled to a range of 0 to 10, occurred in about 4 hr. Therefore, the filled pycnometers were held in the baths for 4 hr

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or somewhat longer, except in a few experiments in which the period was from 3.5 to 4 hr.

Simultaneous density measurements were made in duplicate on each of 65 cream samples at 0.95 and 9.85 C. Also, 11 samples were studied at only one temperature, two at 0.95 and nine at 9.85 C. Ten of these were comparative experiments in which duplicate samples were held at one temperature for various periods of time.

The percentage of fat in all samples was determined in duplicate by the Babcock method and the percentage of total solids in 57 samples was determined in duplicate by the Mojonnier method.

#### CREAM SAMPLES

A total of 76 samples of cream from diverse sources was examined throughout a year, to obtain results representative of commercial creams. Fifteen samples (14 raw and one pasteurized) were obtained from the USDA Dairy at Beltsville, Maryland. Each sample represented about 20 gal of high-test cream from a mixed herd. Four Beltsville samples (three raw and one pasteurized) were separated in the laboratory and represented from 2 to 3 gal of cream. Twenty-one tank and tank-truck

samples (15 pasteurized) were supplied by two dairies and a milk producers' association plant, and represented quantities ranging from 1,000 to 5,000 gal of cream, except for five samples from about 550 gal of cream. Thirty-six retail samples of cream were from four local dairies, including six samples of approximately 30% cream which were prepared by combining equal amounts of 20 and 40% cream.

The work schedule made it necessary to hold the samples for various periods of time at about 40 F before the density was measured. Most of the samples were held in the dairy or laboratory for one or two days, and a few for several days. The retail samples were from two to seven days old. Usually, the tank samples were measured the same day obtained, but a few were held overnight.

#### RESULTS AND DISCUSSION

The data before analysis are not presented here because of their number. Photostats of the tabulated results can be obtained by writing to the author.

A scatter diagram revealed a linear relationship between density and fat for cream containing from 18 to 48.5% fat (Figure 1).

TABLE 1  
Linear regression equations relating density of cream to milk fat, total solids, and nonfat solids  
Density = Constant + [(regression coefficient, b) × (constituent factor)]

Constituent factor	Average value of constituent	Coefficient of determination <sup>a</sup>	Regression statistics		
			Constant term	Regression coefficient, b (with its standard error) <sup>b</sup>	Standard error of estimate <sup>c</sup>
<hr/>					
All samples, 57: <sup>a</sup>	—————(%)—————		—————( <i>Density measurement units</i> )—————		
Milk fat	37.00				
0.95 C		93	1.03331	−.000626 (±.000023)	±.00131
9.85 C		95	1.03123	−.000770 (±.000024)	±.00135
Total solids	42.08				
0.95 C		91	1.03920	−.000691 (±.000029)	±.00145
9.85 C		94	1.03857	−.000852 (±.000029)	±.00150
Nonfat solids	5.08				
0.95 C		85	0.98328	+ .005288 (±.000294)	±.00189
9.85 C		84	0.97037	+ .006374 (±.000378)	±.00243

<sup>a</sup> Coefficient of determination is the percentage of variation in density associated with variation in constituent factor.

<sup>b</sup> Average amount of increase or decrease in density which occurs with each increase of 1% in indicated constituent factor. The figure in parentheses indicates the limits of change to be expected in the regression coefficient two times out of three from repeated sets of samples.

<sup>c</sup> Indication of the agreement expected between a density value estimated from the equation and the true density. Estimated values can be expected to be distributed about the true values as follows: Within one standard error for two out of three estimates; within two times the standard error for 19 out of 20 estimates; within three times the standard error for 99 out of 100 estimates.

<sup>d</sup> Average density values: 1.01014 at 0.95 C; 1.00273 at 9.85 C.

TABLE 2

Linear regression equations relating density of cream to the milk fat content  
 Density = Constant + [(regression coefficient, b) × (milk fat percentage)]

Kind and no. of samples	Coeffi- cient of deter- mina- tion <sup>a</sup>	Aver- age milk fat con- tent	Aver- age den- sity value	Regression statistics		
				Constant term	Regression coefficient, b (with its standard error) <sup>b</sup>	Standard error of estimate <sup>c</sup>
		(%)	(Density measurement units)			
All samples, 57:		37.00				
0.95 C	93		1.01014	1.03331	-.000626 (±.000023)	±.00131
9.85 C	95		1.00273	1.03123	-.000770 (±.000024)	±.00135
Retail, 33:		33.60				
0.95 C	96		1.01243	1.03352	-.000628 (±.000023)	±.00099
9.85 C	97		1.00558	1.03092	-.000754 (±.000025)	±.00106
Nonretail, 24:		41.69				
0.95 C	69		1.00699	1.02891	-.000526 (±.000075)	±.00162
9.85 C	79		.99882	1.02816	-.000704 (±.000077)	±.00165
Milk fat, from 36 to 46%, 41:		40.01				
0.95 C	51		1.00835	1.02838	-.000500 (±.000079)	±.00131
9.85 C	62		1.00050	1.02887	-.000709 (±.000089)	±.00148

<sup>a</sup> Coefficient of determination is the percentage of variation in density associated with variation in milk fat content.

<sup>b</sup> Average amount of increase or decrease in density which occurs with each increase of 1% in milk fat content. The figure in parentheses indicates the limits of change to be expected in the regression coefficient two times out of three from repeated sets of samples.

<sup>c</sup> Indication of the agreement expected between a density value estimated from the equation and the true density. Estimated values can be expected to be distributed about the true values as follows: Within one standard error for two out of three estimates; within two times the standard error for 19 out of 20 estimates; within three times the standard error for 99 out of 100 estimates.

There was a similar relationship between density and the total solids (Figure 2). The straight lines calculated by the method of least squares are shown in both figures.

A line relating density to nonfat solids would not fit the points quite as closely. It would slope in the opposite direction, since the density of cream increases with an increase in the nonfat solids constituent of the cream.

Table 1 gives the regression statistics for the equations relating density at 0.95 and 9.85 C to milk fat, total solids, and nonfat solids, each calculated for the 57 samples on which determinations of both the fat and total solids percentages had been made. The ranges of density at 0.95 and 9.85 C were, respectively, 1.00133 to 1.02164 and 0.99302 to 1.01656.

From the indicated values of the standard error of estimate for density at about 1 C, it can be shown that 19 out of 20, or 95%, estimated density values based on the equations in Table 1 could be expected to represent the true values as follows: Within ±.00262 when based on milk fat; within ±.00290 when based on total solids; and within ±.00378 when based on nonfat solids.

Table 2 shows regression statistics relating density to milk fat for cream samples grouped by source and by milk fat percentage: All 57 samples, as in Table 1, had a fat content ranging from 18 to 48.5%, with one-fourth of the samples having fat percentages below 37 (the lower quartile), one-fourth above 42 (the upper quartile), and with the central half divided equally above and below a median of 38.4%;

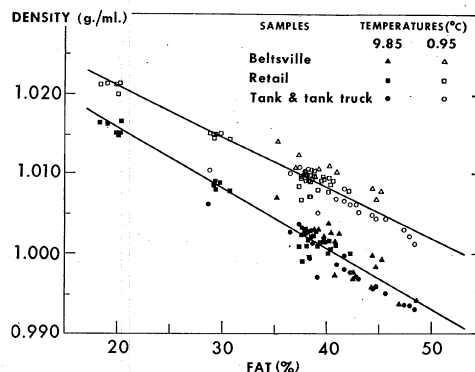


Fig. 1. Relationship of density to the percentage of fat in cream at 0.95 and 9.85 C.

33 samples from retail sources with fat content ranging from 18 to 42%, with lower quartile at 29%, upper quartile at 39%, and the median at 37.8%; 24 nonretail samples with fat content ranging from 29 to 48%, lower quartile at 39%, upper quartile at 45%, and the median at 42.1%; and 41 samples out of both sources with fat content ranging from 36 to 46%, lower quartile at 38%, upper quartile at 42%, and the median at 38.8%. The 24 nonretail samples included 21 tank truck samples and three samples from the USDA Dairy at Beltsville, Maryland.

From the last column in Table 2, it can be concluded that densities at about 1 C estimated for retail samples could be expected 19 out of 20 times to represent the true values within  $\pm .00198$ , if based on the equation calculated on the basis of the 33 retail samples. This represents an improvement from the  $\pm .00262$  expected from the equation based on all 57 samples or from the equation calculated from the 41 cream samples limited to a fat content from 36 to 46%. For general purposes though, the equations based on all 57 samples could be considered to be the most useful.

Multiple regression equations presented in

Table 3 indicate that only a slight improvement in the accuracy of estimated densities would be expected if the percentage of nonfat solids is included in the equation. From the standard error of estimate for the equation based on all 57 samples for density at about 1 C, it can be shown that 19 out of 20, or 95%, estimated density values can be expected to represent the true values within  $\pm .00232$ , as compared with  $\pm .00262$  for the comparable linear equation.

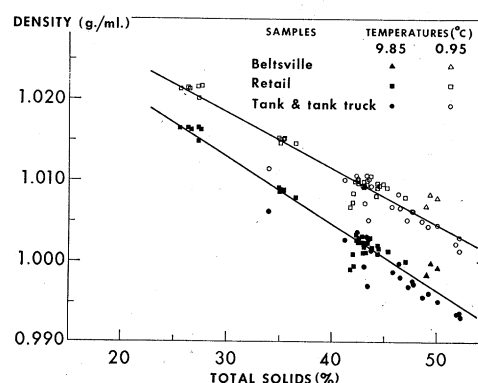


FIG. 2. Relationship of density to the percentage of total solids in cream at 0.95 and 9.85 C.

TABLE 3

Multiple regression equations relating density of cream to percentage of milk fat and nonfat solids

$$\text{Density} = \text{Constant} + [b_1 \times (\text{milk fat percentage})] + [b_2 \times (\text{nonfat solids percentage})]$$

Samples	Coeffi- cient of multiple determi- nation <sup>a</sup>	Regression statistics			Standard error of estimate <sup>c</sup>
		Constant term	Net regression coefficient (with its standard error), <sup>b</sup> density on		
			Milk fat, b <sub>1</sub>	Nonfat solids, b <sub>2</sub>	
<hr/>					
(%)		<i>(Density measurement units)</i>			
<hr/>					
All samples, 57: <sup>a</sup>					
0.95 C	95	1.01847	-.000455 (±.000048)	+.001672 (±.000420)	±.00116
9.85 C	96	1.01930	-.000632 (±.000052)	+.001345 (±.000459)	±.00127
Retail samples, 33: <sup>e</sup>					
0.95 C	97	1.01800	-.000432 (±.000062)	+.001659 (±.000499)	±.00086
9.85 C	98	1.01405	-.000541 (±.000066)	+.001803 (±.000533)	±.00092

<sup>a</sup> Coefficient of multiple determination is the percentage of variation in density associated with variations in percentages of milk fat and nonfat solids in cream.

<sup>b</sup> Average increase or decrease in density which occurs with each increase of 1% in milk fat and in nonfat solids. The figures in parentheses indicate the limits of change to be expected in the regression coefficients two times out of three from repeated sets of samples.

<sup>c</sup> Indication of the agreement expected between a density value estimated from the equation and the true density. Estimated values can be expected to be distributed about the true values as follows: Within one standard error for two out of three estimates; within two times the standard error for 19 out of 20 estimates; within three times the standard error for 99 out of 100 estimates.

<sup>d</sup> Average values for 57 samples: Density: 1.01014 at 0.95 C; 1.00273 at 9.85 C; milk fat: 37.00%; nonfat solids: 5.08%.

<sup>e</sup> Average values for 33 retail samples: Density: 1.01243 at 0.95 C; 1.00558 at 9.85 C; milk fat: 33.60%; nonfat solids: 5.39%.

The density values obtained in this study were compared with those of the National Bureau of Standards (2), the U. S. Department of Agriculture (5), Thomsen (8), and Mohr and Kaufmann (4), over the range of 4.4 to 10 C for creams containing 20, 35, and 40% milk fat. Although the latter measured and reported specific volumes, the corresponding density values were computed here for comparative purposes. The highest average density values reported by any one of these workers, including the present study, for 20% cream at 4.4 and 10 degrees were found to be 0.59 and 0.47% higher than the lowest average density values, respectively. Similarly, for 35% cream they were 0.88 and 0.76% higher, and for 40% cream they were 1.08 and 0.84% higher. The U. S. Department of Agriculture (5) values were higher than the others, and for 35 and 40% cream, those of Thomsen (8) were lower than the others. It appears, therefore, that small changes in existing weight-volume tables for low-temperature ranges may be desirable. A study of the application of the results of this research to weight-volume tables is continuing.

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